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The Last Word: Living with Paradox

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Living with PARADOX

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One late evening in June a student who just scored a perfect exam approached me with a bewildered look and asked: "I know I gave you the correct answers, but I don't understand what I wrote". She was referring to the paradoxical nature of matter, an issue whose resolution shook the very foundations of science at the turn of the twentieth century and led to the establishment of Quantum Theory.

In our class discussions we had reviewed the great debates pitting established true believers on the particle nature of light against younger thinkers who supported its wave-like identity. The heavyweights in these debates included Einstein, Bohr and Planck, but it took a young and brash aristocrat and physicist, Louis deBroglie, to reconcile this paradox. DeBroglie postulated that, indeed, light had a dual particle-wave nature and that both matter and light are interchangeable. In the macroscopic world of Isaac Newton it was obvious to everyone that all matter occupied space and possessed tangible properties ("particle"), but in the sub-microscopic domain of electrons and subatomic particles nature behaves differently. Or does it? This fundamental question forced scientists to remove all preconceived notions and think boldly that under certain situations light acts as a wave spread over a large region of space. Thus light (electrons) behave as both waves and particles, continuously being affected in their behavior by their environment.

Was my nineteen-year-old student buying this argument? "Only to pass your course", she admitted jokingly. Did I understand what I was explaining? Maybe. But I will admit that my comprehension of quantum mechanics improves incrementally each passing decade, just as my appreciation of Bach's organ music (both listening and playing) deepens annually.

As a parting comment I told the student that in our "real" (macroscopic) world we conceive matter predominently as particle since its wave properties are exceedingly small. Conversely, some subatomic particles (photons) are so small that their behavior can best be explained as wave-like. Electrons fall between these two extremes and their behavior as waves and particles allows biologists to study structure of tissues by electron microscopy.

The particle-wave paradox deepened in 1927 when Werner Heisenberg postulated the Uncertainty Principle bearing his name. He showed by elegant mathematical equations that, in the world of the atom, one cannot know precisely both the energy and position of an electron simultaneously. Philosophers were quick to apply this principle of physics into other disciplines and concluded that the very act of observation (experimentation) changes the "reality" of the observed object. Simply stated, the electron does not possess objective properties and my conscious act of observing it will somehow effect it. It was left to that great Dane, Niels Bohr, to synthesize these ideas into a comprehensive notion of complimentarity. Each half of this paradox (wave-particle) is true, but each has a limited range of applicability and in a reciprocal manner. Bohr had studied the Chinese notion of yin/yang philosophy and set out to explain additional paradoxes in nature, using concepts of probability and relativity, rather than Newtonian physics or Aristotelian logic. In a memorable series of lectures on PBS television the mathematician-biologist J.J. Bronowski extrapolated Heisenberg's views into human affairs. His plea for tolerance and acceptance of races, religions, and cultures different than one's own was so very eloquent and moving; a triumph of natural philosophy over ignorance and prejudice.

We clearly observe paradoxes in the macroscopic world of health, economics and defense which often leave us perplexed and depressed. Modern medical science takes a Cartesian reductionist approach to the human body, viewing it as much like a wonderful mechanical clock. Too often we are overwhelmed by the financial cost of "treatment" of such dysfunctions as cardiac, cancerous and diabetic diseases. The understanding of cell biology and biochemical pathways should be augmented by achievement of harmony between mind and body, something the West can learn from the accumulated wisdom of Eastern philosophies. An emerging clue to the resolution of our health status is a shift of responsibility from physicians to individuals who practice preventive and holistic medicine through proper hygiene, nutrition and habitat.

On the economic scene the alternate ways of producing energy pose several dilemmas. With each "enery crisis" (based on fossil fuel prices) new sources of power sprout briefly. The most promising of these, nuclear reactors, has persisted long enough to demonstrate its darker image through the Chernobyl disaster. We must live in the shadow of immediate death by explosion or progressive degeneration of health from radioactive nuclear waste. Perhaps the ultimate paradox involves the mutlinational policies of producing nuclear weapons, all nations professing their desire for peace and justice. It is depressing to imagine the implications of "MAD" (mutually assured destruction) policies on a bright Sunday afternoon, but we have entered the nuclear age with a "no exit" sign behind us.

A final paradox involves life and the eventuality of death. If my devout grandmother's wish is to be realized, I shall forever be with her in heaven since I promised and succeeded in being a "good" child (that contract excluded my later years). Without invoking theology/philosophy, nature does indeed strike a Mephistophelian bargain on this paradox too. There are certain bacteria which reproduce by cell division (asexual) and thus never "die". They have lived forever, alas with no awareness or differentiation. Lately, a billion years ago, the bargain included two inescapable phenomena we have come to take for granted: sex and death. Life and to invent sex (chromosomal pairing) to generate evolutionary changes, then complete the cycle through death. Some paradox... ■

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